FEATURES OF PALAEOZOIC TECTONISM IN SOUTH AUSTRALIA

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[Read 12 May 1966]

SUMMARY

Evidence on Palaeozoic tectonism in South Australia is restricted both in time and space; most of the areas mentioned here are from the Mt. Lofty-Flinders Ranges, locus of the Adelaide Geosyncline.

The Indulkana area on the south-east edge of the Musgrave Block suggests a pre-Ordovician folding of the Upper Proterozoic sequence related to a fault in the crystalline basement. In the Great Artesian Basin, subsurface information shows a long history of uplift of the Gidgealpa anticline and a deformation between the Ordovician and Permian.

In the Central Flinders Ranges the Blinman diapir was rising in the Upper Proterozoic; sinking of a graben associated with the Oraparinna diapir ceased before Middle Cambrian time. From fossil evidence, the main Palaeozoic orogeny in this area must have begun no earlier than Middle Cambrian. In the Mount Lofty Ranges there is stratigraphic evidence for mild tectonism in late Precambrian and early Cambrian time, as exemplified by unconformities in the Truro area and the White Point Conglomerate on Kangaroo Island. Using a K-Ar age of the Encounter Bay granite (457 x 10^6 years) the main orogeny in the south may be placed between Middle Cambrian and Middle Ordovician; there were at least two phases of folding.

Tectonism produced varying effects such as gentler, more open folds accompanied by diapirism in the central Flinders Ranges and steeper, more crowded folds accompanied by basement folding and thrusting in the south and Olary regions. Deformation is generally more intense in anticlinal areas.

INTRODUCTION

This review has been prepared as a South Australian contribution to a symposium on Palaeozoic tectonism in Australia; the writer has acted mainly as an assembler of information, much of it previously published.

The major orogeny in South Australia has long been attributed to the lower Palaeozoic. The effects of this orogeny, seen mainly in the Mt. Lofty and Flinders Ranges, have been described by such earlier workers as Howchin (e.g. 1926), but an overall appreciation of this orogeny, exemplified in the 1960 Tectonic Map of Australia, has been dependant upon the progress of regional geological mapping in South Australia. Hence, the structural analyses of Campana (1955; 1958 in Glaessner and Parkin) of the Mt. Lofty and Flinders Ranges result from mapping by the Geological Survey in these regions; current mapping by the Survey and research at the University of Adelaide should make a future study most fruitful.

Such an analysis is not attempted in this paper, which presents instead the results of work from certain selected areas.

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TECTONIC FRAMEWORK

Although some of the tectonic subdivisions of South Australia are more recent than the Palaeozoic, it is convenient to see where the particular areas under discussion fall in relation to the whole tectonic framework of South Australia. The names used in Fig. 1 are mainly those of Hills (1965) with modification based partly on Thomson (1965) who has presented a more detailed tectonic subdivision, and Dickinson and Sprigg (1953).

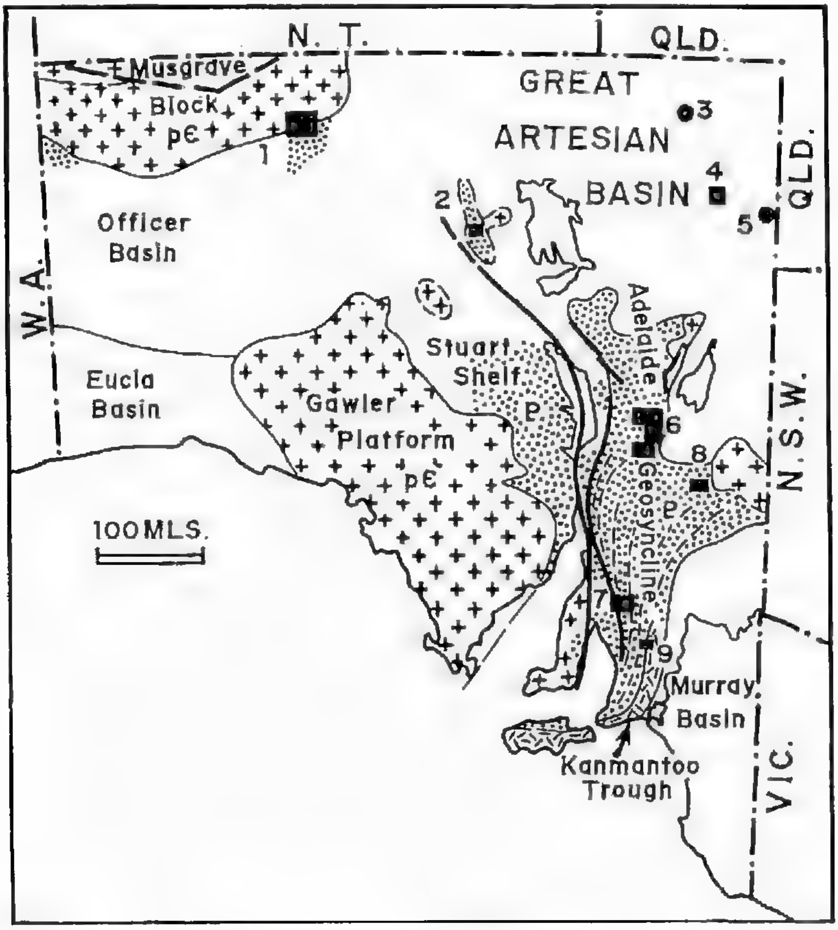


Fig. 1. Map of South Australia showing main tectonic units (after Thomson, 1965, and others). Precambrian crystalline basement: shown by crosses, as in the Gawler Platform and Musgrave Block. Upper Proterozoic and lower Palaeozoic sedimentary rocks: dots. Lower Palaeozoic sedimentary rocks of the Kanmantoo Group: as in the Kanmantoo Trough. Lineaments appear as heavy lines; the Torrens Lineament is shown passing through Lake Torrens on the eastern edge of the Stuart Shelf and running south along the eastern coast of Yorke Peninsula toward Kangaroo Island. Numbered localities are as follows: 1, Indulkana Range; 2, north-east of Boorthanna; 3, Pandieburra No. 1 Well; 4, Gidgealpa anticline; 5, Dullingari No. 1 Well; 6, Blinman-Hawker region; 7, Clare area; 8, Weekeroo area; 9, Truro area.

The largest areas of older Precambrian crystalline basement are exposed in the Musgrave Block and Gawler Platform. Proterozoic and Cambrian sedimentary rocks are known in the Adelaide Geosyncline, where they are thickest and moderately to strongly folded, and on the Stuart Shelf, where they are flat-lying. The Adelaide Geosyncline, termed a miogeosyncline by Sprigg (1952), may have extended well to the north-west of the Flinders Ranges. In the north-east, Palaeozoic rocks are known to underlie Mesozoic sediments of the Great Artesian Basin. The Officer Basin is suspected to contain a significant thickness of Palaeozoic sedimentary rocks, but this remains to be tested. The Murray and Eucla Basins are areas of Tertiary sedimentation: the Murray Basin is underlain by rocks similar to those of the Kanmantoo Trough.

Palaeozoic rocks have a limited surface extent in South Australia. As may be seen in Fig. 1, the areas involved are mainly in or near the Mt. Lofty-Flinders Ranges where the results of the early Palaeozoic orogeny are well displayed. A welcome and interesting exception is the bore-hole information available from the Gidgealpa area in the Great Artesian Basin.

NORTH-WESTERN REGION

The Musgrave Block (Hills, 1965) is flanked to its south-west by gently inclined basal conglomerate and quartzite thought to be uppermost Proterozoic in age (Johnson, 1963). These sediments, which Thomson (1965) refers to his Giles Shelf, are conceivably co-extensive with the sedimentary content of the Officer Basin, which was possibly a subsiding area in the Upper Proterozoic and Palaeozoic. Gravity surveys (Mumme, 1965, p. 122) suggest that the deeper part of the Officer Basin lies between latitudes of about 27.5 and 29 degrees south.

A little more evidence on the age and nature of tectonism in the north-west is provided on the south-eastern edge of the Musgrave Block in the Alberga area, described by R. P. Coats (1963). In the Indulkana Range (Fig. 2) in the south-eastern corner of the Alberga 1:250,000 map area, the gently-folded Mt. Chandler Sandstone unconformably overlies more strongly folded Upper Proterozoic sedimentary rocks of the Adelaide System. The Mt. Chandler Sandstone contains *Scolithus* and *Cruziana*, which, together with lithological similarity to the Pacoota-Stairway sequence of the Amadeus Basin, are suggestive of an Ordovician age (H. Wopfner, personal communication). The uppermost beds of the Adelaide System, which includes the Chambers Bluff Tillite, are not older than Sturtian and may be Marinoan, hence there must have been a period of strong folding between Upper Proterozoic and the time of deposition of the Mt. Chandler Sandstone.

The intensity of folding of the Proterozoic beds increases markedly near a faulted contact with the older Precambrian near the north-western edge of the Indulkana Range. As can be seen in Fig. 2, more open folding south-east of the Range is replaced by steep isoclinal overturned folding near the fault. The folding of the Adelaide System is thus at least partly influenced by the faulted edge of the crystalline basement. Axes of the gentle post-?Ordovician folds are also aligned sub-parallel to this edge. The final phase of intense faulting rejuvenated established fractures in the older Precambrian rocks and gave rise to extensive crush zones containing pseudotachylite.

PEAKE AND DENISON REGION

The Peake and Denison Ranges form a series of Precambrian inliers in the western part of the Great Artesian Basin. Stratigraphically and structurally they resemble the Flinders Ranges, and trend in a north-north-westerly direction parallel to fold axes in quartzites and slates of the Adelaide System. Folding can be dated only between the broad limits of Upper Proterozoic and Permian.

As indicated by Reyner (1955, p. 12) folds in the Adelaide System rocks are fairly open with dips of the order of 20 to 50 degrees, but there are zones covering smaller areas where folds are locally steep and are usually accompanied

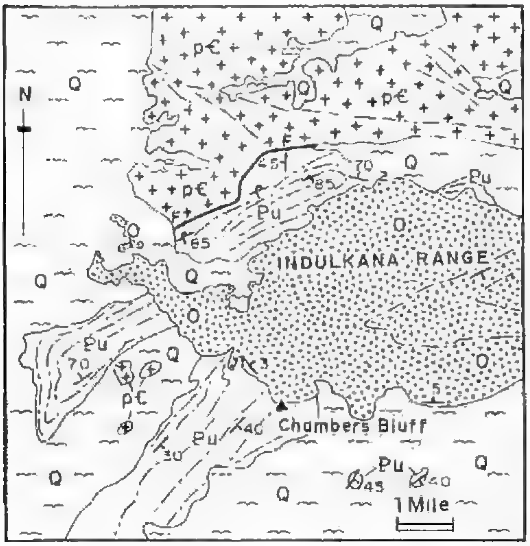
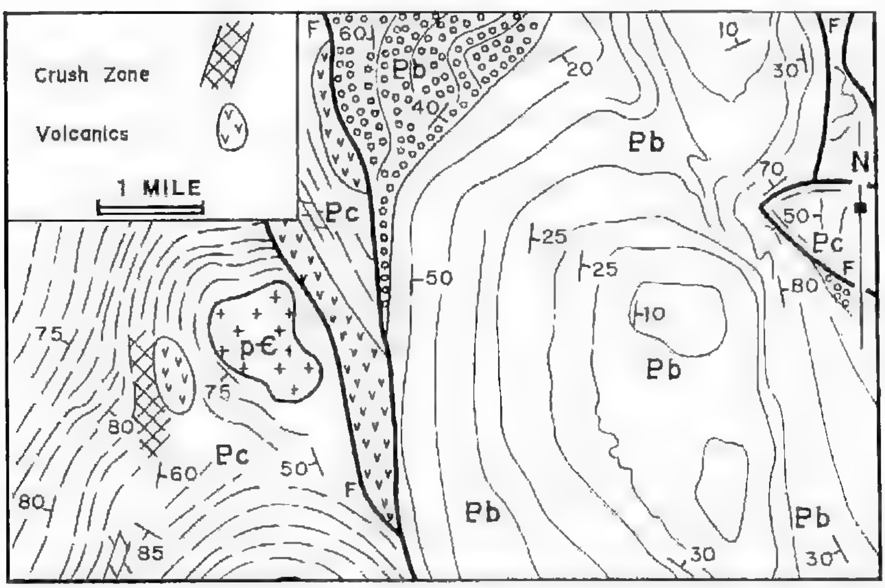


Fig. 2 (left). Geological sketch-map of the Indulkana Range area, based on Coats, 1963. Q: Quaternary deposits; O: Mt. Chandler Sandstone; Pu: Upper Proterozoic sedimentary rocks. Crosses: crystalline basement; F: fault

Fig. 3 (below). Geological sketch-map of an area north-east of Boorthanna, after Reyner, 1955, and Thomson, 1964. Pb, Pc: Upper Proterozoic sedimentary rocks of the Burra Group and Callanna Beds. Crosses: crystalline basement. F: fault.



by faults. Fig. 3, which is based partly on unpublished work by Coats and Thomson (Thomson, 1964, Fig. 3) and the Boorthanna and Cadlareena 1-mile geological maps, shows a broad basin flanked by faulted, steeply-dipping anticlinal areas. Movement with the greatest relative vertical component is concentrated in these faulted, anticlinal areas.

GREAT ARTESIAN BASIN

The Gidgealpa anticline, one of a series of structures in the Great Australian Artesian Basin in the north-east of South Australia, has been outlined by seismic surveys of the United Geophysical Corporation for Santos Ltd. and Delhi Australian Petroleum Ltd. Drilling of seven wells, five of which produce commercial quantities of gas, has shown that the structure has had a complex tectonic history. This history has been outlined principally by J. Harrison and W. J. Greer of Delhi Australian Petroleum Ltd., to which company I am indebted for permission to use confidential reports.

Gidgealpa No. 1 well, shown in the structure contour plan, Fig. 4, and section, Fig. 5, is located on the more gently-dipping eastern limb of the anticline and has penetrated in its deepest part fossiliferous Cambrian rocks. Within the Cambrian beds at a depth of 10,000 feet there is a suspected thrust fault.

Dipmeter values indicate a slight angular unconformity between a Cambrian Limestone and overlying sandstone of probable Permo-Carboniferous age. Pollen and spore analysis by W. K. Harris in 1965 (unpublished) of correlative beds in Merrimelia No. 1 demonstrates a post-lower Carboniferous age for these rocks. Hence, in the lower part of Gidgealpa No. 1 well there is evidence for Upper and Middle Cambrian volcanism and thrusting followed by uplift and erosion between early Upper Cambrian and Permian.

The dating of younger movements may be made with reference to Fig. 5. The Gidgealpa anticline was active in post-lower Carboniferous time as evidenced by the absence of the ?Permo-Carboniferous sandstone from Gidgealpa Nos. 2, 3, 4 and 6 and the presence of a widespread erosional break at the base of the Permian. There is a marked thinning of the Permian and Triassic over the structure which suggests a continuation of movement through the Permian. In Gidgealpa No. 1 the Permian is 1,000 feet thick and contains about 15% thickness of coal beds, but in Gidgealpa No. 2 near the crest of the anticline the Permian has thinned to 182 feet and contains 10% coal beds.

Relevant information is also provided from the Delhi-Santos Pandieburra No. 1 and Dullingari No. 1 wells (respectively north-west and south-east of Gidgealpa). Between 6,970 feet and total depth of 7,253 feet, Pandieburra No. 1 penetrated steeply-dipping quartzite and shale of palaeontologically-determined Lower Ordovician age. These beds are overlain unconformably by flat-lying Triassic sandstone; Permian is absent. In Dullingari No. 1, Middle to Upper Ordovician beds dipping at 45 to 60 degrees are at a depth of 9,050 feet overlain with angular unconformity by Permian boulder clay. Thus, both these wells demonstrate a post-Lower Ordovician Palaeozoic tectonism.

ADELAIDE GEOSYNCLINE

The overall pattern of folding and faulting in the Adelaide Geosyncline has already been described by several authors, notably Sprigg (1946), Campana and Webb in Glaessner and Parkin (1958), Coats (1964), and Thomson (1965), and is featured in the Tectonic Map of Australia of 1960. It is proposed here to select only a few small areas for comment.

Blinman Region

The Blinman 1:63,360 geological map (Dalgarno, Johnson and Coats, 1965) covers an area of fairly open folding in the Flinders Ranges at the northern end of what Campana terms the Blinman axial culmination. Most of the northern Flinders Ranges are characterized by relatively broad structures with moderate dips except near local disturbances such as diapiric structures and major faults.

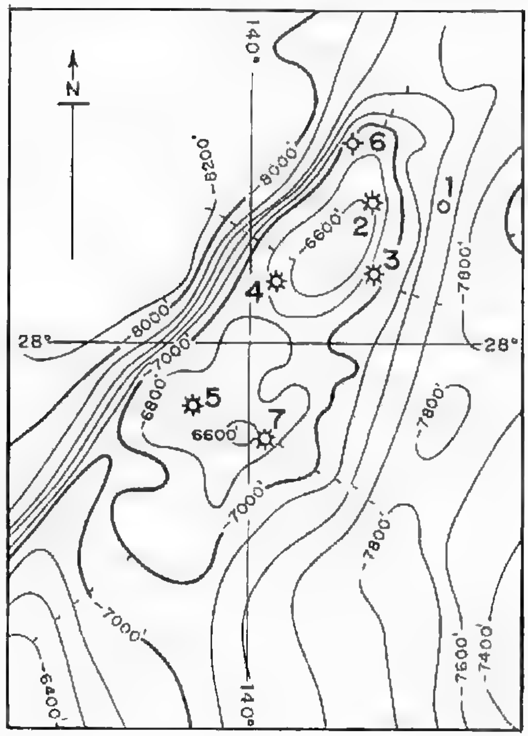


Fig. 4. Structure contour plan of the Gidgealpa anticline, after Delhi Australian Petroleum Ltd., showing positions of wells. Contours are depths of the top of the Permian below sea-level. Maximum dip of the north-west flank of the anticline is about 12 degrees.

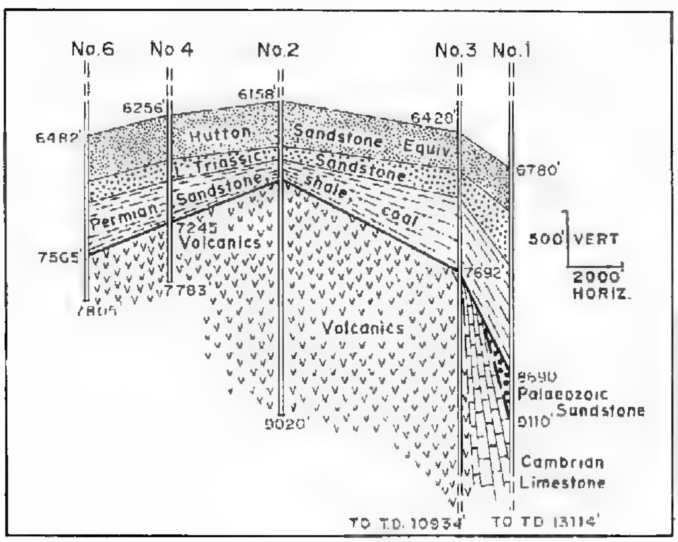


Fig. 5. Diagrammatic geological cross-section of the Gidgealpa anticline, after Delhi Australian Petroleum Ltd.

Features of interest in the Blinman area (Fig. 6) are the steep up-turning of rocks of the Umberatana Group around the Blinman diapir, the presence of a system of cross-faults apparently related at least in part to the diapir, and certain sedimentary features suggestive of relatively upward movement during the Lower Cambrian. The sedimentary features are pebble beds in the Wilkawillina Limestone near the Wirrealpa diapir, thinning of certain units and the presence of disconformities. As suggested by Dalgarno (1964, p. 139), there appears to be a widespread disconformity at the base of the Billy Creek Formation (Upper Lower to Middle Cambrian) which transgresses from Oraparinna shale down to Wilkawillina Limestone in the Blinman 1:63,360 area.

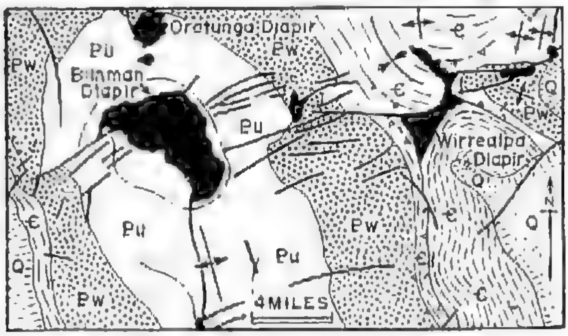


Fig. 6. Geological sketch-map of the Blinman area, based on the Blinman 1:63,360 geological map. Black areas: disturbed rocks of the Callanna Beds in diapirs. Pu, Pw: sedimentary rocks of the Umberatana and Wilpena Groups of the Adelaide System. Dashed areas: Cambrian sedimentary rocks. Q: Quaternary deposits. Heavy lines: faults. Lines with triangular projections indicate disconformities.

Coats (1964) indicates some of the evidence for the age of diapirism. The Blinman diapir provided some of the detritus in sediments of the Umberatana Group and the youngest movement of the Wirrealpa diapir post-dated the Lower Cambrian Oraparinna Shale.

South-east of the Blinman area Dalgarno (1964) has described a graben related to the Oraparinna diapir. The graben was subsiding during deposition of the Lower Cambrian Hawker Group. Thickness of the Group within the graben is 4,100 feet compared with only 200 to 1,500 feet outside. A biostrome was controlled by active movement of one of the faults during the Lower Cambrian. Thickness of the Middle Cambrian Wirrealpa Limestone is not obviously affected. This area also gives palaeontologically a lower time-limit of Middle Cambrian for the main period of folding.

Burra-Quorn Region

The open and dis-oriented folding of the Blinman-Oraparinna region is replaced near Hawker by steeper north-easterly trending folds which extend south into the Quorn area. The first sharp structure south-east of Wilpena Pound is shown in Fig. 7 and is a faulted syncline involving the Pound Quartzite and overlying Cambrian beds.

A further example of faulting associated with steeper folding is provided in the Burra region. In the western part of the Clare 1:63,360 area (Forbes, 1964), just west of Clare, is a narrow zone of tightly folded and faulted rocks of the lower part of the Adelaide System. This disturbed zone extends north and south; near Spalding it contains small intrusive bodies of dolerite.

East of this zone is a contrastingly broader and more open syncline, pitching gently north, which is succeeded to the east by further more open parallel anticlines and synclines.

Olary Region

Structural relationships between older Precambrian crystalline basement and the Adelaide System in the Olary region have been outlined by Campana (Campana and King, 1958), who concludes that folding of the crystalline basement was the active agent in diastrophism.

Structures in the Adelaide System are fairly open away from the migmatite inliers but are frequently steep or overturned close to them. The main direction

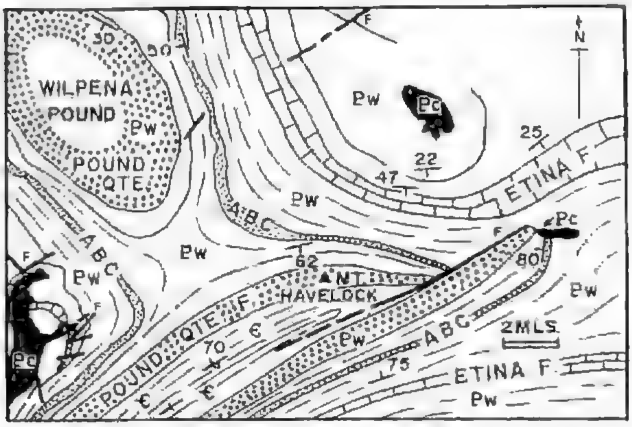


Fig. 7. Geological sketch-map of an area south-east of Wilpena Pound, based on part of the Parachilna 1:250,000 geological map (Dalgarno, 1966). Pc: disturbed rocks of the Callanna Beds in diapirs. Pw: Wilpena Group. ABC: ABC Range Quartzite.

of schistosity is north-easterly in both older and younger Precambrian. However, a prominent zone of overthrust through McDonald Hill (about 7 miles north-east of Olary) is oriented in a north-westerly direction. A recent re-examination of the Plumbago-Weekeroo area by Talbot (personal communication, Dr. J. L. Talbot, University of Adelaide, 1965; see Fig. 8) indicates that folding of the crystalline basement was accompanied by steep east-dipping thrusts which extend some way into the Upper Proterozoic sedimentary rocks. Talbot notes that where the basal conglomerate of the Adelaide System overlies basement schist it is much more severely folded than where it overlies basement gneisses.

Southern Region

In the southern Mount Lofty Ranges the structures resulting from Palaeozoic tectonism have been outlined in the course of regional geological mapping. The older Precambrian crystalline basement appears as anticlinal cores which are overthrust to the west within strongly folded Upper Proterozoic and Cambrian rocks.

The youngest fossiliferous pre-Permian rocks in this southern area are Lower Cambrian in age (Daily, 1956, 1963; Abele and McGowran, 1959). Thus the main Palaeozoic orogeny occurred between Lower Cambrian and Permian. Other relevant published dating evidence is provided by Evernden and Richards (1962), who give a potassium-argon age of 457 x 10^6 years (Middle Ordovician) for the Encounter Bay granite. This would indicate a Middle Ordovician or earlier age for the orogeny, since field evidence suggests the granite to be largely post-tectonic (e.g. Bowes, 1954, p. 212).

There is evidence, particularly strong in the Truro area, for local movement prior to deposition of the Cambrian. North of Truro, Coats (1959) has mapped an unconformity at the base of a sequence of Cambrian trachytic lavas, schist and marble. Coats shows that in places the base of the Cambrian truncates beds within the underlying upper Proterozoic. The Cambrian volcanics were in turn eroded and the detritus incorporated in the overlying basal beds of the Kanmantoo Group. Marked thinning of the trachyte immediately south of a fault is suggestive of movement prior to deposition of the Kanmantoo Group. Movement on a hinge-line during deposition of the Kanmantoo Group is also proposed by Horwitz, Thomson and Webb (1959). The hinge-line is related to a thrust and results in an increase in thickness from 3,000 to 20,000 feet of the Inman Hill Formation near Ashbourne.

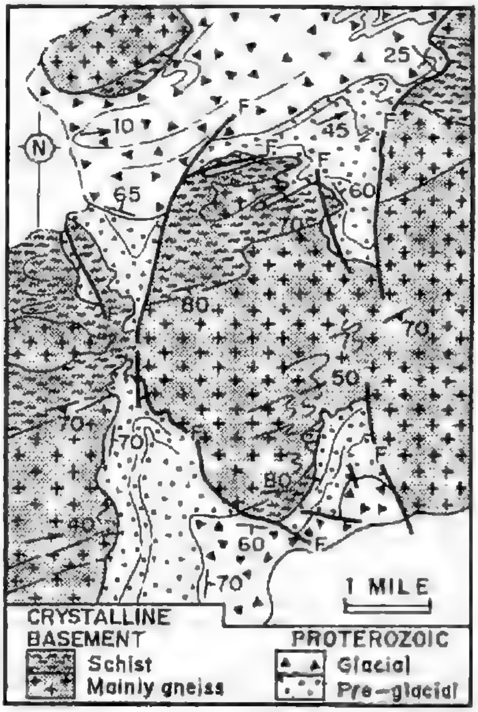


Fig. 8. Geological sketch-map of the Weekeroo area based on a map of J. L. Talbot. This area demonstrates folding and faulting (shown by heavy lines) of the crystalline basement.

Horwitz, Thomson and Webb (1959, Pl. 1) show evidence for truncation of the Upper Proterozoic by basal Kanmantoo Group greywacke near Mt. Charles. A similar truncation by Lower Cambrian beds appears on the Barker 4-mile geological map north-west of Macclesfield (Thomson and Horwitz, 1962).

Daily (1956, pp. 124-128) infers uplift and erosion of the lower Cambrian Archeocyatha limestone and older rocks on Kangaroo Island during the Lower Cambrian. The White Point Conglomerate contains boulders of Archeocyatha limestone, quartzite, and igneous and metamorphic rocks. This conglomerate is overlain conformably by fossiliferous sedimentary rocks extending into upper Lower Cambrian. The upper unfossiliferous part of the succession may be of Middle Cambrian age.

Structural petrological studies by Talbot (1964), Offler (1963) and K. J. Mills (1964) in the Mount Lofty Ranges indicate at least two phases of deformation of Adelaide System and Kanmantoo Group rocks. In the Torrens Gorge area

(Talbot) and north of Palmer (Mills) the earlier deformation characterized by slaty cleavage was succeeded by later folding which produced crenulation cleavage.

Mills has been able to date thrust-wrench faults north of Palmer as post-metamorphism and folding, in view of the fact that they displace metamorphic facies boundaries. He correlates these faults with thrusts, described by Sprigg, associated with overturned anticlinal cores in the western part of the Mt. Lofty Ranges.

YORKE PENINSULA

In the central part of Yorke Peninsula there are gently folded Upper Proterozoic and Lower to Middle Cambrian rocks with dips of 15 degrees resting on older Precambrian gneisses and schists (Crawford, 1965, p. 57). There is a mantle of Permian boulder till. This slightly mobile shelf area (Spencer Shelf of Sprigg, 1952) is bounded on the north-east by the Yararoo overthrust, which is associated with tight, overturned folds (Horwitz, 1961, p. 7). If one can assume that the gentle folding of the shelf accompanied the steeper folding of the geosynclinal environment then the main period of folding was post-Middle Cambrian and pre-Permian. The Lower and Middle Cambrian shelf sediments show no evidence of contemporaneous orogeny.

CONCLUSIONS

The preceding sketches of selected areas provide local data on Palaeozoic tectonism and examples of the kind of deformation resulting from it. This information may thus be summarized on a time basis and on a structural basis.

Among the examples chosen, the earliest closely-dated Palaeozoic movements are those of diapirs which were active from late Precambrian until late Lower Cambrian. In the eastern Mt. Lofty Ranges minor folding of the Adelaide System occurred probably in uppermost Precambrian, when the Kanmantoo Trough began to develop. In the Lower Cambrian there was subsidence of the Oraparinna graben, local uplift east of Blinman and on Kangaroo Island, and possibly the Truro volcanism. The Kanmantoo Trough continued to develop, accompanied by local differential movement in the eastern Mt. Lofty Ranges

In Middle to Upper Cambrian time, the best-dated events were the volcanism and thrust-faulting at Gidgealpa; up-arching of this structure also occurred in the pre-Permian and Permian. Remaining Palaeozoic movements listed in this paper are known only within a wide time range. Using the evidence of the Encounter Bay granite and the Yorke Peninsula Middle Cambrian, the main lower Palaeozoic orogeny in the Mount Lofty Ranges would appear to have occurred between Middle Cambrian and Middle Ordovician. Information from the Dullingari and Pandieburra wells is significant because it indicates a second (post-Ordovician) Palaeozoic deformation in the north-east of South Australia.

The effects of Palaeozoic tectonism in South Australia are most obvious east of the Stuart Shelf; the eastern edge of this relatively stable area is probably the largest observable external feature which may be claimed to have influenced Palaeozoic deformation. Its eastern margin, if carried around the eastern coast of Yorke Peninsula, is roughly paralleled by the fold axes of the Mt. Lofty and Flinders Ranges.

In the Olary region there is good evidence that during folding, which was accompanied by faulting, the crystalline basement and immediately-overlying Adelaide System behaved as a single unit. Another feature of the Olary area is the steepening of dips of Adelaide System rocks adjacent to the crystalline cores. Similarly, in the Burra area anticlines are frequently narrower and steeper than synclines. In the Blinman region and north, dips are locally steep near discontinuities, such as diapirs, faults and crystalline basement. Thus, at least locally, movements with a large vertical component were important during the Palaeozoic orogeny.

On the basis of the Tectonic Map, one may crudely subdivide the Adelaide Geosyncline into a central area of relatively close parallel folds and a northern area typified by less frequent and more gentle folds and the proliferation of diapirs. This subdivision requires explanation, as also does the frequency and parallelism of folds in the central area. In spite of the evidence for local vertical movements, it seems to be necessary to invoke some horizontal compression to explain folding and thrusting in the Adelaide Geosyncline.

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